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Diversity and Ecology of Mammals in Fragmented Habitats in Kalkaska County, Michigan

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Abstract

A small mammal survey was conducted in Kalkaska County, Michigan, from 2002 to 2013. Four habitats were surveyed: an old *Pinus strobus* (white pine) forest, a young white pine forest, a kettle bog, and a *Populus grandidentata* (bigtooth aspen) forest. The study site is 4.39 km SE of Big Twin Lake (44°47.147' N, 84°55.659' W) and is 372 m in elevation. In addition, mammal records from an earlier study (1999 and 2001) are reported herein; that study was conducted in a maple/beech forest habitat located 2.8 km NNW and a spruce/cedar swamp habitat located 3.5 km SW of the 2002–2013 study site. Lastly, records of small and medium-sized mammals that were photographed, observed, or opportunistically salvaged from other locations in Kalkaska County are reported. In total, 29 species were recorded from 1999 to 2013. Numbers and diversity of mammals captured per habitat type varied by year. The results of this study illustrate the need for long-term and repeated monitoring of a region to fully document mammalian diversity and abundance trends.

Key words: aspen forest, kettle bog, long-term, mammalian diversity, white pine forest

Introduction

The diversity and distribution of the mammals of northern Michigan is well-studied (Burt 1946; Baker 1983; Kurta 2017). However, because of human induced environmental change it is important to monitor mammalian diversity in areas that previously had been surveyed (Patterson 2003). Furthermore, with large annual changes in abundance of small mammals it is possible to miss species that would otherwise be counted in longer-term studies (Hice and Velazco 2012; Hayes and Schadin 2017). The objective of this study was to survey the mammals of Kalkaska County, Michigan, and to determine the diversity and abundance levels of small mammals in an ecologically fragmented landscape. Old white pine forests are now relic habitats in northern Michigan. Only small fragments of this once widespread habitat exist today within the more dominant northern hardwood forests consisting of *Acer* sp. (maple) and *Fagus* sp. (beech).

HABITAT DESCRIPTION

Annual small mammal surveys were conducted from 2002 to 2013 at a white pine/bog site (Fig. 1). Based on tree core data from the largest white pine trees at the study site, the forest began growing between 1890 and 1934. Tree core data indicate a fire scar at about 1917 in one of the largest trees in the old white pine forest. A nearby kettle bog created a fire shadow that protected what now remains of the older white pine forest. Few white pines in the area survived outside of the fire shadow. Today the landscape is a mosaic of different forest types, with the dominant forest surrounding the study site being northern hardwood or maple/beech. The fragmented nature of the habitat at this site made it of particular interest for study (Fig. 1). The soil type of the three forested trapping sites is sandy glacial till (spodosol) and the geology of the study area is classified as ice contact stratified outwash (J. Bratton, pers. comm.; Dickmann and Leefers 2006).

Successional changes on the study site (from 2002 to 2013) were most noticeable on the kettle bog. A long-term drought caused a decrease in the water table, which allowed the germination of pines. Another ecological impact that was probably a result of the drought was the loss of beaver (*Castor canadensis*) from the bog. Beaver were present just prior to the start of the study. They cut birch at the edge of the young white pine forest, dug channels in the bog, and established a lodge near the bog's center. The birch logs, cut in 2001, were not moved and consequently decomposed. Although absent during the course of this study, beaver had a substantial ecological impact because of their channels and the logs left behind in the young pine forest.

The older white pine forest is 1.25 hectares in area. The mean height of the white pines is 29.3 m (range 39.4–21.7 m, $n = 18$). The mean diameter at breast height (1.4 m above the ground) is 32.1 cm. The mean basal area (m^2/ha) is 53.3, density (stems/ha) 479, and the importance value (relative frequency + relative dominance + relative density) of white pine is 99.5. This older white pine forest is unusual because it is on the eastern edge of a kettle bog. The edge allows light to penetrate to the forest floor most of the afternoon hours and as a result young pine trees grow next to mature pine trees (Fig. 1). Other species of trees that occur in the older white pine forest are *Acer rubrum* (red maple), *Populus grandidentata* (big-tooth aspen), and *Viburnum* sp. (Nannyberry).

The young white pine forest is similar to the old white pine forest in that both are dominated by white pine, but the younger trees are only about two thirds as tall as trees in the older forest. The young white pine forest is 2.0 hectares in area. The mean height of the white pines is 17.59 m. (range 13.30–21.48 m, $n = 11$). The mean diameter at breast height is 22.9 cm. The mean basal area (m^2/ha) is 23.3, density (stems/ha) 440, and the importance of white pine is 77.8. Other species of trees in the young white pine forest are *Pinus resinosa* (red pine), *Populus tremuloides* (quaking aspen), and *Prunus serotina* (black cherry) (B. Mayfield, pers. comm.).

In 2004, a big-toothed aspen forest was added to the trapping sites (Fig. 1). This habitat is dominated by big-tooth aspen and is 0.54 ha in area. All the big-toothed aspens appear to be of similar height (about 10 m) and age. There are red pines and black cherry on the western edge of the habitat.

A 3.29 ha kettle bog lies adjacent and to the west of both young and old white pine forests and was also the site of a trapping grid. Kettle bogs were formed as depressions left by glacial ice, which filled in with organic material over time (Dickmann and Leefers 2006). The soil type in the bog is histosol. Three groups of plants dominate the kettle bog: sedges on the outer edge of the bog, *Chamaedaphne calyculata* (leatherleaf), and *Sphagnum* sp. (peat moss). Small patches of *Cladonia cristatella* (British soldier lichen) also are found. The elevations of the sites range from 371 m in the bog to 380 m in the aspen forest.

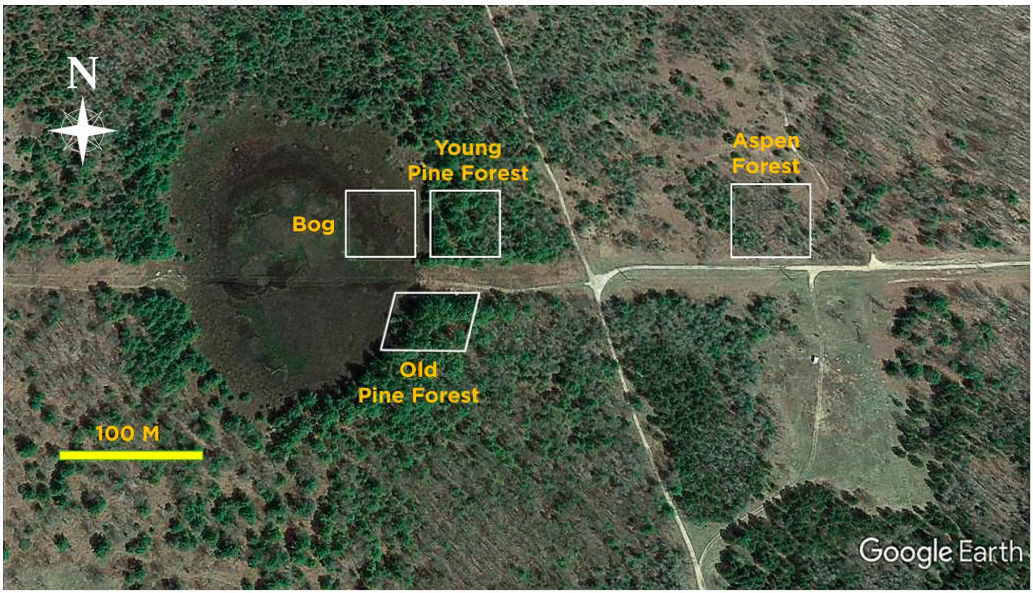

Figure 1. Locations and habitats of the four trapping grids (Aspen Forest, Bog, Old Growth White Pine Forest, and Young Growth White Pine Forest) utilized in this study, 2002–2013. Aerial image from Google Earth.

MATERIALS AND METHODS

Two sizes of Sherman traps were used during the study: large, measuring 38 cm x 10.5 cm x 12 cm, and small, 23 cm x 8.5 cm x 9 cm. In each habitat type (Fig. 1), Sherman traps were arranged in a rectangular grid configuration. Each grid had five parallel lines of traps placed 10 m apart with 10 Sherman traps positioned on each line 5 m apart, totaling 50 traps in each habitat. To maintain a buffer zone that minimized interference from unpaved roads, power line clearing, and edge effect, all trapping grids were placed as fully as possible in their respective habitats. The size of the grids was limited by the area of each habitat, but when compared to a review of similar surveys, the distance between traps and the area of each grid was in line with the majority of similar surveys (Bowman et al. 2001). Animals were recorded as having moved from one grid to another on only a few occasions.

Pitfall traps also were used during the study to target species of shrew. Pitfall traps were constructed by digging a series of holes and placing buckets (15 cm x 19.5 cm) in them. Two-by-four boards connected the pits and acted as drift fences to guide the animals into the trap. Wooden platforms were placed over each bucket to protect captured animals from predation as well as prevent rainfall from flooding the trap. The number of pitfalls used in a single line ranged from three to five buckets. Studies conducted in 2007 and 2009 also included pitfall traps placed in the aspen forest habitat. Including pitfalls and Sherman traps, the total number of trap nights was 20,032. Tomahawk traps were placed on the bog grid starting in 2002. In 2007 and 2008, a tomahawk trap was placed in the old pine forest, and in 2009, a tomahawk trap was placed in the aspen grid as well. Mist nets were set in a number of habitats to assess bat diversity; however, mist netting was mostly unsuccessful.

Bait used in Sherman traps consisted of seeds, shredded carrots, potatoes, millet, milo, and corn. Traps were set twice a week in the evening and checked the following morning. The species, gender, weight (using

a pesola scale), and location were recorded and animals were given individually numbered ear tags. During the study, most animals were marked and released. Specimens that either died or were salvaged from other areas were vouchered into the Abilene Christian University Natural History Collection (ACUNHC).

The numbers of individuals per species were determined by direct count of animals marked with an ear tag or collected for vouchers. The guidelines for the treatment of wild mammals in research as presented by the American Society of Mammalogists (Sikes et al. 2011) were followed. Kurta (2017) was followed for identification and nomenclature.

Weather data were obtained from the Grayling, Michigan, weather station located 22 km southeast of the study site. Precipitation totals for eight years of this study were below the mean precipitation of 852.9 mm, and four years (2006, 2008, 2011, and 2013) were above the mean precipitation level. Although the Grayling weather station did not post complete monthly rainfall data in 2011, data that was recorded for 2011 was on track to be above mean precipitation.

Additional specimen records that were obtained from an earlier survey (conducted in 1999 and 2001 in maple/beech forest and spruce/cedar swamp habitats), as well as mammals observed, photographed, and specimens salvaged from locations other than the four trapping grids also have been noted in the species accounts.

RESULTS

The abundance of small mammals in the study area, as suggested by the total number of animals marked and released or collected as vouchers, peaked in 2007 and 2012 (Table 1). With the exception of those two years, the total small mammals trapped across all four habitats ranged from a low of 17 in 2008 to a high of 59 in 2003. This study was conducted during a prolonged drought, and it was therefore expected that there would be a correlation between years of higher precipitation and peaks in trapping success the following year. This trend was seen for 2006/2007 and 2011/2012, but not for 2008/2009, and the correlation was not significant. The following accounts document the mammal species trapped, photographed, and observed during this study.

ORDER EULIPOTYPHLA
Family Soricidae
Blarina brevicauda (Say, 1823)
Northern Short-tailed Shrew

Specimens of *Blarina brevicauda* that were collected from the study site included 3 males, 13 females, and four sex unknown (ACUNHC 567–576, 756, 777, 825, 837, 876, 1058, 1320, 1539, 1635, 1636). This species was caught in all the habitats sampled on the study site. The most (17 individuals) were trapped in 2003 and the numbers were similar in the three habitats (bog, old white pine, and young white pine forest) sampled that year (Table 2). When the aspen forest habitat was added to the collecting sites, *B. brevicauda* was present there as well. *Blarina brevicauda* is a habitat generalist (Smith and Smith 2001), and that is reflected in the results of this study. *Blarina* numbers dropped to zero in 2010 and never recovered during the course of this study (Table 1). It is hypothesized that the overall drier conditions and lower water table on the study site resulted in poor habitat conditions for *Blarina brevicauda.*

Sorex cinereus **Kerr, 1792**
Masked Shrew

There were 12 males, 17 females, and 17 sex unknown specimens of *Sorex cinereus* collected from the study site (ACUNHC 754, 819–824, 826, 830, 831, 833, 834, 1017–1019, 1027, 1059–1063, 1391–1394, 1398, 1535, 1631–1633, 1717, 1721, 1723–1731, 1821–1825).

Sorex cinereus was found on all the study site grids and was captured every year except 2011. *Sorex cinereus* was common in the bog and the old pine forest and least common in the aspen forest (Table 2). *Sorex cinereus* was one of the most common species captured over the course of the study.

Table 1. Number of captures of common species of small mammals for each year of the study. These values represent the combined numbers for each species for all four trapping grids. These numbers were calculated by direct count of marked and vouchered animals.

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sorex cinereus	21	12	8	4	13	13	8	2	4	0	1	5
Blarina brevicauda	4	17	1	1	2	2	0	7	0	0	0	0
Tamiasciurus hudsonicus	6	2	1	7	7	9	1	2	4	0	5	2
Glaucomys sabrinus	0	0	0	0	5	3	0	0	1	1	0	1
Tamias striatus	5	9	7	7	4	18	2	12	12	5	11	21
Zapus hudsonius	6	10	4	3	0	8	0	2	1	1	6	2
Microtus pennsylvanicus	5	4	11	2	8	15	2	2	3	10	15	3
Microtus pinetorum	0	0	0	0	1	0	0	1	1	1	0	0
Myodes gapperi	3	0	2	6	3	5	1	0	0	0	9	1
Synaptomys cooperi	1	0	6	0	2	1	2	2	4	7	13	6
Peromyscus leucopus	3	5	1	5	10	30	1	12	1	2	11	3
Total	54	59	41	35	55	104	17	42	30	27	71	44

***Sorex hoyi* Baird, 1857**
American Pygmy Shrew

Three female and one sex unknown specimens of *Sorex hoyi* were vouchered from the site (ACUNHC 872, 1026, 1545, 1634). *Sorex hoyi* was the smallest and least common shrew on the study site. This species was captured only four times during the study and it was always found in the bog habitat. Specimens were captured in 2003, 2004, 2009, and 2010.

Family Talpidae
***Scalopus aquaticus* (Linnaeus, 1758)**
Eastern Mole

Scalopus aquaticus were not captured during this study, but mole trails were observed in forests around Big Twin Lake. One female specimen of Scal*opus aquaticus* (ACUNHC 1482) was salvaged on the campus of the Au Sable Institute/Big Twin Lake in 2009 (44°49'21.86" N, 84°57'18.62" W).

ORDER CHIROPTERA
Family Vespertilionidae
***Myotis lucifugus* (Le Conte, 1831)**
Little Brown Bat

A female *Myotis lucifugus* specimen (ACUNHC 750) was salvaged from a structure at the Au Sable Institute campus (44°49'21.86" N, 84°57'18.62" W) in 2001, and two specimens of unknown sex (ACUNHC 1718, 1719) were salvaged from a residential area around Little Twin Lake (44°48'47.04"N, 84°58'27.06" W) in 2012.

***Eptesicus fuscus* (Beauvois, 1796)**
Big Brown Bat

One male specimen (ACUNHC 578) was collected in 1999 from a clearing for an oil pump-jack in a maple-beech forest (44°48'34.48" N, 84°56'37.86" W). A second specimen, sex unknown (ACUNHC 1501), was salvaged from a garage next to Big Twin Lake (44°49'40.84" N, 84°58'02.61" W) in 2009.

Table 2. Captures per habitat and per year for selected, most frequently captured species that were found in more than one habitat. Numbers in parenthesis represent the number of individuals that were captured in more than one habitat, and the letters signify that more than one individual per species per year was found on a different grid.

	Sorex cinereus	*Blarina brevicauda*	*Tamias striatus*	*Tamiasciurus striatus*	*Peromyscus leucopus*
		2002			
Aspen Forest	N/A	N/A	N/A	N/A	N/A
Bog	15	1	0	0	0
Old Pine Forest	5	2	4	3	2
Young Pine Forest	1	1	1	3	1
		2003			
Aspen Forest	N/A	N/A	N/A	N/A	N/A
Bog	5	5	0	0	0
Old Pine Forest	5	6	7	2	3 (1)
Young Pine Forest	2	6	2	0	2 (1)
		2004			
Aspen Forest	0	0	4	0	1
Bog	3	0	0	0	0
Old Pine Forest	4	1	3 (1)	1(1)	0
Young Pine Forest	1	0	2 (1)	1(1)	0
		2005			
Aspen Forest	0	0	6	0	1
Bog	1	0	0	0	0
Old Pine Forest	2	0	0	5	2
Young Pine Forest	1	1	1	2	2
		2006			
Aspen Forest	0	0	1	1	2
Bog	3	0	0	0	1
Old Pine Forest	6	0	2	4	2
Young Pine Forest	4	2	1	2	5
		2007			
Aspen Forest	2	0	4	6	12
Bog	7	0	0	0	4 (1a)
Old Pine Forest	2	0	13	2	7 (1b)
Young Pine Forest	2	2	1	1	9 (1a, b)

Table 2. (cont.)

	Sorex cinereus	*Blarina brevicauda*	*Tamias striatus*	*Tamiasciurus striatus*	*Peromyscus leucopus*
			2008		
Aspen Forest	0	0	1	0	0
Bog	4	0	0	0	0
Old Pine Forest	3	0	1	0	1
Young Pine Forest	1	0	0	1	0
			2009		
Aspen Forest	0	2	4	2	2
Bog	0	1	0	0	1
Old Pine Forest	2	2	7	0	6
Young Pine Forest	0	2	1	0	3
			2010		
Aspen Forest	0	0	3	3	0
Bog	4	0	0	0	0
Old Pine Forest	0	0	5	0	1
Young Pine Forest	0	0	4	1	0
			2011		
Aspen Forest	0	0	0	0	0
Bog	0	0	0	0	1
Old Pine Forest	0	0	4	0	2
Young Pine Forest	0	0	1	0	0
			2012		
Aspen Forest	0	0	3	1	5
Bog	0	0	0	0	0
Old Pine Forest	0	0	3	1	4
Young Pine Forest	1	0	5	3	2
			2013		
Aspen Forest	0	0	6 (1a)	1	0
Bog	1	0	0	0	0
Old Pine Forest	4	0	8 (1a, b)	0	0
Young Pine Forest	0	0	9 (1b)	1	3

ORDER CARNIVORA
Family Mustelidae
***Mustela frenata* Lichtenstein, 1831**
Long-tailed Weasel

Two specimens of *Mustela frenata*, one male and one sex unknown (ACUNHC 753, 766) were collected in the same trap at 44°47'56.59" N, 84°53'34.02" W in 2001. This species was captured (and released) four times on the study site. The first capture in 2004 was in the young white pine forest, and all subsequent captures (2005, 2007, and 2013) were in the old white pine forest.

***Neovison vison* (Schreber, 1777)**
American Mink

A female Mink, *Neovison vison*, was photographed on the campus of the Au Sable Institute in 1999. One male specimen (ACUNHC 1715) was salvaged from a road near Seven Bridges Park, 8.55 km NW Kalkaska in 2012 (44°48'47.16" N, 85°13'19.15" W).

***Taxidea taxus* (Schreber, 1777)**
American Badger

In 2008, an adult *Taxidea taxus* (probably a female) and three young were photographed in an open power line clearing between the aspen and old white pine forest trapping grids.

Family Procyonidae
***Procyon lotor* (Linnaeus, 1758)**
Northern Raccoon

Procyon lotor were trapped and photographed in the old white pine forest and kettle bog habitats in 2003 and 2009. This species was frequently seen in the residential areas.

ORDER RODENTIA
Family Sciuridae
***Sciurus carolinensis* Gmelin, 1788**
Eastern Gray Squirrel

Three female specimens (ACUNHC 579, 1487, 1819) of *Sciurus carolinensis* were obtained from roadkill near Big Twin Lake (44°49'21.86" N, 84°57'18.62" W) in 1999, 2009, and 2013. *Sciurus carolinensis* was observed frequently in residential areas around Big Twin Lake.

***Sciurus niger* Linnaeus, 1758**
Eastern Fox Squirrel

Sciurus niger was not observed as often as *S. carolinensis*. However, a male specimen (ACUNHC 1389) was salvaged from a road intersection next to Big Twin Lake (44°49'59.12" N, 84°57'37.00" W) in 2008.

***Tamiasciurus hudsonicus* (Erxleben, 1777)**
Red Squirrel

Four males, two females, and one specimen of unknown sex (ACUNHC 580, 581, 773, 874, 1080, 1275, 1546) of *Tamiasciurus hudsonicus* were either vouchered from the study site or collected at Big Twin Lake. This species was captured every year of the study except 2011. The highest number caught was in 2007 with nine individuals captured. This species was found on all the forested grids but was collected and observed most frequently in the young and old white pine forests.

***Glaucomys sabrinus* (Shaw, 1801)**
Northern Flying Squirrel

One female (ACUNHC 577) specimen of *Glaucomys sabrinus* was collected from a maple/beech forest (44°48'34.48" N, 84°56'37.86" W) in 1999. This species was captured on all the forested sites. One individual was found in both the old and young white pine forests in 2007. This species was found on all three forest grids in 2006 and 2007, with five and three individuals, respectively. However, in 2010, 2011, and 2013, only single individuals were captured in the Aspen forest.

***Glaucomys volans* (Linnaeus, 1758)**
Southern Flying Squirrel

One specimen of unknown sex (ACUNHC 1630) was salvaged from a seasonal cabin. No *Glaucomys volans* were captured at the study site. However, they have been seen at bird feeders in nearby residential areas near Big Twin Lake.

***Marmota monax* (Linnaeus, 1758)**
Woodchuck

One male *Marmota monax* (ACUNHC 1000) was salvaged on the campus of the Au Sable Institute in 2003. The habitat where this specimen was taken was a mixed male/beech/pine forest.

***Ictidomys tridecemlineatus* (Mitchill, 1821)**
Thirteen-lined Ground Squirrel

One female specimen of *Ictidomys tridecemlineatus* was salvaged near a residential area at 44°49'46.03" N, 85°00'30.79" W (ACUNHC 2086). This species was never seen or captured on the study site. These animals were, however, seen in places where people maintained lawns or other grassy areas.

***Tamias striatus* (Linnaeus, 1758)**
Eastern Chipmunk

Three males, nine females, and two *Tamias striatus* of unknown sex were vouchered (ACUNHC 582, 583, 764, 768, 818, 836, 1015, 1242, 1246, 1390, 1698, 1699, 1720, 1818).

Tamias striatus were caught every year on the study site, and recaptures of this species were common on all forested sites. This was the only species where individuals were marked one year and recaptured in a subsequent year. This was also one of only four species that was marked on one grid and later found on a different grid. The number of *T. striatus* captured on the forested sites ranged from two in 2008 to 21 in 2013.

Family Castoridae
***Castor canadensis* Kuhl, 1820**
American Beaver

One skull (ACUNHC 760) of *Castor canadensis* was found on the Au Sable Institute campus in 2001. Beaver were active on the study site before the water level dropped too low just prior to the study. Beaver are present in other localities in Kalkaska County, including a pond adjacent to the campus of the Au Sable Institute.

Family Dipodidae
***Napaeozapus insignis* (Miller, 1891)**
Woodland Jumping Mouse

One female *Napaeozapus insignis* (ACUNHC 999) was vouchered from the study site. This species was found only once in 2004 (in the aspen forest) and once in 2005 (in the bog).

***Zapus hudsonius* (Zimmermann, 1780)**
Meadow Jumping Mouse

Two male specimens of *Zapus hudsonius* were vouchered from the study site (ACUNHC 827, 1302).

This species was caught 90% of the time in the bog and 7% in the aspen forest. *Zapus hudsonius* was most common in 2003 with 10 captures.

Family Cricetidae
***Microtus pennsylvanicus* (Ord, 1815)**
Meadow Vole

Three male and seven female specimens of *Microtus pennsylvanicus* were vouchered (ACUNHC 755, 769, 772, 817, 1057, 1303, 1304, 1716, 1722, 1820) during this study. This species was caught every year of the study with a high of 15 in 2007 and 2012 and lows of two in each of the years 2005, 2008, and 2009. This species was most commonly captured in the bog. These data are congruent with past studies that show that this species prefers open habitat and not forests (Getz 1961; Kurta 2017).

***Microtus pinetorum* (Le Conte, 1830)**
Woodland Vole

One male specimen (ACUNHC 873) was collected at a site near Big Twin Lake (44°49'40.13" N, 84°58'01.07" W). *Microtus pinetorum* was never common at the study site. It was only trapped one time in each of the years 2006, 2009, 2010, and 2011. *Microtus pinetorum* was found twice in the aspen forest and twice in the old white pine forest that has patches of thick duff for burrows.

***Myodes gapperi* (Vigors, 1830)**
Southern Red-backed Vole

One male and one female specimen (ACUNHC 815, 832) of *Myodes gapperi* were vouchered during this study.

With the exception of 2012, *M. gapperi* was not present in great numbers. In 2012, this species was one of the more common small mammals, with nine individuals captured. No *M. gapperi* were captured in 2003, 2009, 2010, and 2011. This species was most commonly captured in the aspen forest.

***Synaptomys cooperi* Baird, 1857**
Southern Bog Lemming

Four males, one female, and one specimen of *Synaptomys cooperi* of unknown sex were vouchered (ACUNHC 816, 1020, 1397, 1544, 1547, 1817). *Synaptomys cooperi* was most common in 2012 with 13 individuals captured. This species was not captured in 2003 and 2005. Of the total captures, 77% were in the bog and 18% were in the old white pine forest-bog ecotone.

***Peromyscus leucopus* (Rafinesque, 1818)**
White-footed Deermouse

Four males and one female (ACUNHC 871, 1081, 1277, 1278, 1483) of *Peromyscus leucopus* were vouchered from the study site. The numbers of *P. leucopus* captured varied from one in several years to 30 in 2007. These animals were identified using tail color patterns.

***Ondatra zibethicus* (Linnaeus, 1766)**
Common Muskrat

Ondatra zibethicus was observed in Lewes Pond on the campus of the Au Sable Institute. There were more observations of this species after 2014 (after the conclusion of this study), perhaps because increased precipitation caused many habitats to flood.

Family Erithrozonitidae
***Erethizon dorsatum* (Linnaeus, 1758)**
North American Porcupine

Erethizon dorsatum were found a number of times on the study site, and photos document its occurrence. In 2009, a juvenile was found in the young white pine forest, and a juvenile and an adult were found in the aspen forest. In 2013, one adult was captured and released in the old white pine forest.

ORDER LAGOMORPHA
Family Leporidae
***Lepus americanus* Erxleben, 1777**
Snowshoe Hare

Two specimens of *Lepus americanus*, a juvenile female (ACUNHC 875) and an adult male (ACUNHC 1543), were salvaged in different years (2003 and 2010, respectively) from the same location (44°46'21.34" N, 84°58'12.33" W). These animals were encountered only in a spruce and cedar swamp 5 km south of Big Twin Lake.

DISCUSSION

The importance of long-term monitoring of mammal populations is demonstrated by this study. For example, in the early surveys *G. sabrinus* was caught in 1999 in a maple/ beech forest, but it was absent from the study site for the first four years of the study, and then the numbers fluctuated from 2006 to 2013 (Table 1). Based on data presented by Myers et al. (2009), *G. sabrinus* seems to be declining in the southern part of its range and is being replaced by *G. volans*. Perhaps *G. sabrinus* persists here because the site is a more northern (Upper Peninsula) habitat type, as compared to the surrounding maple/beech forests (K. Sytsma, pers. comm.). Species distribution predictions are usually based on abiotic factors, but biotic factors such as the presence of the old white pine forest itself may play a role (Krebs and Myers 1974; C. Krebs, pers. comm.). Therefore, some species may be able to persist when they otherwise would have been displaced by southern species at the same latitude. Other species that help make the case for long-term trapping in a single location include *S. hoyi*, *N. insignis*, and *M. frenata* because these species were rarely encountered. Furthermore,

B. brevicauda was common in the early years of the study and then not trapped after 2010 on the study site (Tables 1 and 2). The loss of *B. brevicauda* is perhaps due to the drying conditions, as these animals prefer moist habitats (Baker 1983). A study that was on the site for only one season would not have encountered the full diversity of mammals.

Throughout all of the surveys, *S. cinereus*, *T. striatus*, *M. pennsylvanicus*, and *P. leucopus* were the most common species taken. These generalist species appear to thrive because of habitat fragmentation (Tables 1 and 2). This finding also is in line with previous indications that fragmentation results in the dominance of generalist species like these over others that may be less suited across differing habitat fragments (Avenant 2000; Nupp and Swihart 2000; Webala et al. 2006).

Trapping data from this study suggested abundance, with the notable peaks in numbers seen in 2007 and 2012. The years when populations of small mammals were at the highest followed brief periods of relief from the drought. Environmental changes such as increased rainfall have been shown to have a great effect on rodent populations (Real et al. 2003). Population increases in all species on the site were usually led by increases of *T. striatus* and *P. leucopus*. The 2012 increase in small mammal numbers was due in part to apparent increases in populations of *T. striatus* and *P. leucopus*, but also to increases in *S. cooperi*, *M. pennsylvanicus*, and *M. gapperi* compared with previous years. One possible argument for the variability in abundance of species across different years of the study was precipitation, because above mean precipitation was followed by a year of increased small mammal abundance (Miller and Getz 1977; Deitloff et al. 2010), but changes in trapping methods such as adding the aspen forest in 2004 also probably had an impact.

With the exception of *B. brevicauda*, the common species could be found almost every year (Tables 1 and 2). This finding seems to be in line with previous research, which indicates that small mammal diversity may remain relatively stable, as long as the species diversity of food sources is also stable (Miller and Getz 1977). Miller and Getz (1977) found little effect of drought on *P. leucopus* and *M. gapperi* populations, which is congruent with this study. *Peromyscus leucopus* and *M. gapperi* seemed to respond positively to higher than mean rainfall in the preceding year.

Noticeable ecological changes occurred during this study due to a prolonged 14-year drought that was punctuated by above mean rainfall. This drought caused the reduction of the water table throughout the region and effected the water levels of lakes and wetlands, including the kettle bog at the study site. The study site bog showed the most visible changes due to the drought, including the loss of beaver and the germination of white pine on the bog or land that was previously too wet to support white pine. These ecological changes should continue to cause changes in the diversity of mammals in Kalkaska County. Continued monitoring is needed for many sites that have had previous studies conducted as wildlife populations are under pressure from human encroachment.

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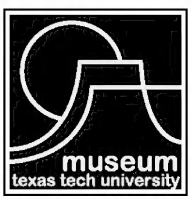

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